Crash-Safe Energy Storage Systems

ARPA-E Workshop

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Executive Summary

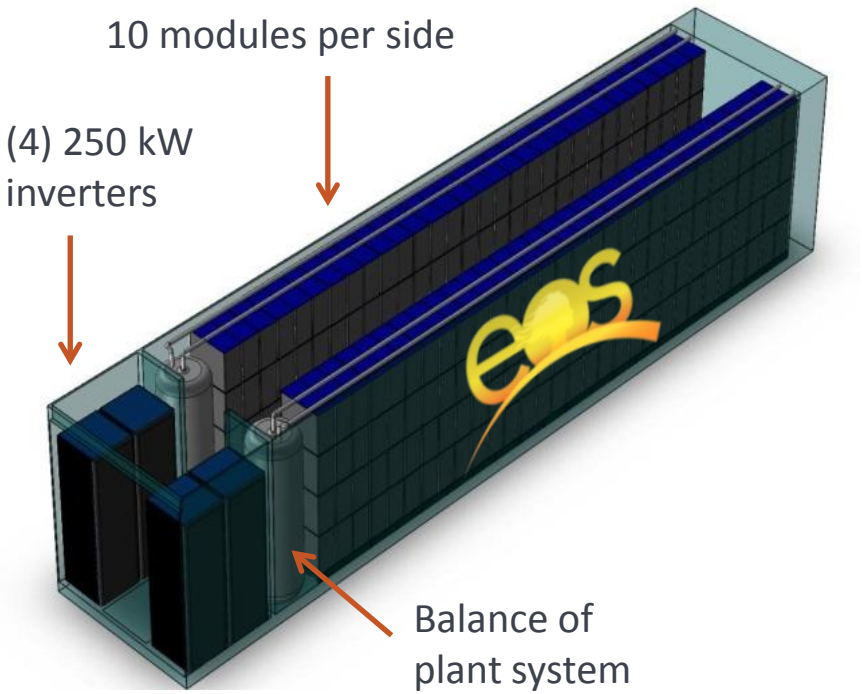
- Eos has developed a safe, reliable, non-toxic, non-combustible, low cost zinc energy storage system for the electric grid that can be sold for **$160/kWh**, rechargeable over 10,000 cycles (30 years)
- Eos is scaling up battery prototypes in 2012/3 in preparation for manufacturing and delivery of MW grid-scale systems to grid customers in 2014
- Eos' low-cost zinc battery technology could enable an EV with 350+ km range that can be produced at the same cost as a gasoline powered vehicle
- While Eos will emphasize grid-storage with its Aurora product, Eos would like to partner with OEMs and battery suppliers to develop:
    1. Eos zinc-air range extender (near-term)
    2. Eos refuelable ***and*** rechargeable zinc-air battery/fuel-cell (long-term)

• One full cycle includes full charge, discharge and additional frequency regulation over the course of one full day.

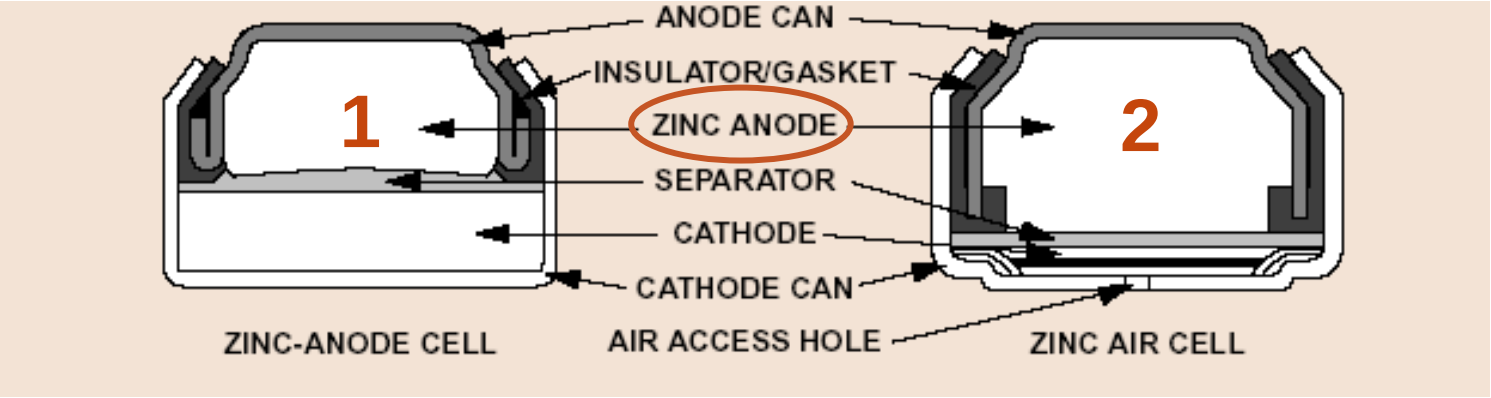
Eos Aurora 1000|6000

Targeted applications define technology characteristics required for profitability

Technology Attributes	
Low-Cost	$1,000/kW or $160/kWh
Long Life	10,000 cycles (30 years)
Ample Storage	1 MW for 6 hours = 6MWh in a 40’ ISO shipping container
Efficient	75% round-trip efficiency
100% Safe	Non-toxic, non-combustible, no risk of catastrophic failure



Why Zinc-Air Batteries?



- Increased amount of anode material in the Zinc-air cell enables greater capacity and energy density at lower cost
- Zinc-air batteries use ambient air as the active cathode material—eliminating material that would normally be carried within the battery

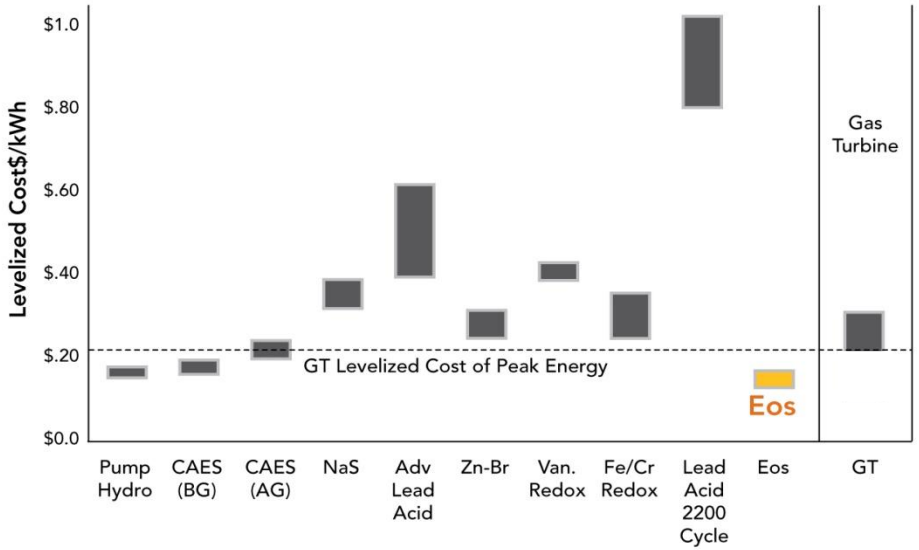
Non-metal Air Batteries

Vs

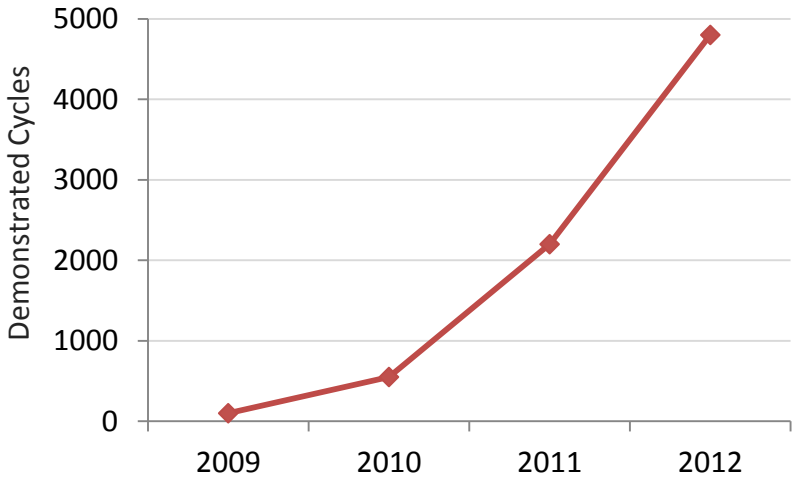
Zinc-Air Battery

Eos Competitive Advantages

Low Cost



Long Life

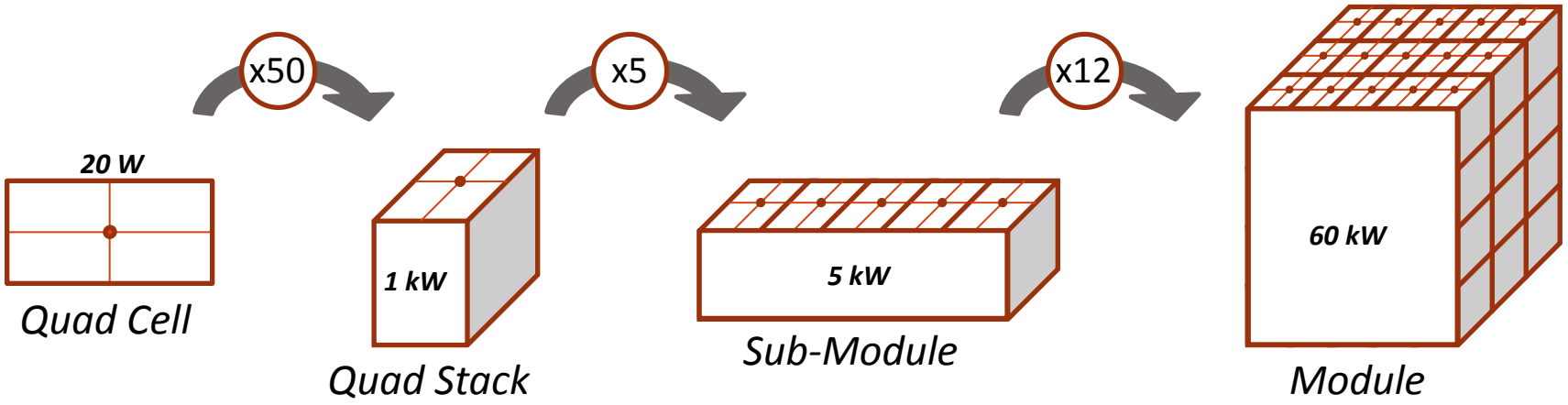


High Energy Density

Safe

*Non-Eos data source: EPRI, Electricity Energy Storage Technology Options, 2010. Natural gas fuel cost range: $6.5 -8/MMBtu. Levelized cost of energy includes cap. fix, and var. costs. Gas peaking cost estimate from Lazard, 2009, midpoint of est. range; assumes: 150MW facility, Capital cost $1,125/MW, Heat rate 10.5 MMBtu/MWh, Cap. factor 10%, Facility Life 35 years, Construction time 25 months. Eos: 2MW plant, 25% cap. factor (6hrs of energy production), Roundtrip efficiency of 75%, Cap. cost for entire system with Eos battery $1.7/watt, O&M costs: $20,000/year for a 2MW/12MWh operating costs, Facility Life 30 years.

Eos Aurora Milestones



Q1 2012 | Q2 2012 | Q3 2012 | Q4 2012 | Q1 2013 | Q2 2013 | Q3 2013 | Q4 2013 | Q1 2014

Eos 1kW Quad Stack completed ahead of schedule

✓1 kW Battery Complete
Aug 2012

2

Sub-Module Complete
March 2013

A

Pilot Line Facility
Sept 2013

3

Multi-MW Manufacturing
Jan 2014

Electric Vehicle Challenges

- Today's EV battery costs $500/kWh
- Goal of $250/kWh

Cost?

Range?

- 40-190 mile range today
- Goal of 350 miles

- 7 hrs to charge 24 kWh Nissan Leaf

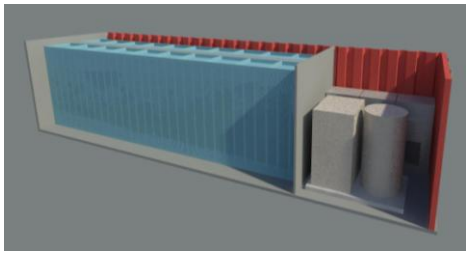
Fueling Time?

Safety?

- Instability of Li-ion results in catastrophic incidents

BCG, Batteries for Electric Cars, 2010.
http://www.nissanusa.com/leaf-electric-car/faq/list/charging#/leaf-electric-car/faq/list/charging

Eos EV Development Roadmap

Current Focus	Near Term (2014)	Long Term (2015-16)
Eos Aurora: Grid-Scale	**1. EV Range Extender**	**2. Refuelable Battery**
	• 30 kWh – 10 kW range extender • Paired with lithium ion • Full system range of 250 km • < $3,500	• 72 kW pulse / 35 kW continuous • 70 kWh for 350 km range • 3 min mechanical refuel • < $10,000
Eos internal resources dedicated to first generation grid product launch	Adaptation of zinc-air technology optimized for power, weight, and mobile application requirements	Innovative battery design requires advanced engineering to enable mechanical refueling

EOS EV Battery Metrics

	Eos EV Near-term goal	Eos EV Med-term goal	Average Lithium Ion	USABC Minimum Goals	USABC Long Term Goals
System Level W/kg	91	145	350	300	400
System Level Wh/kg	120	180	100	150	200
System Level W/l	208	530	350	460	600
System Level Wh/l	273	**620**	100	230	300
Cost USD/kWhr	100	**<100**	500	<150	100

EOS densities are system level including balance of plant

A dual EOS and power battery can add kW with small weight and cost penalty

Eos excels at system level costs per Kwh

Li Ion avg incl A123, Ener1, LG Chem, Altairnano & Dow Kokum: specs from web site, white papers, reports and extrapolation

EV Development Focus

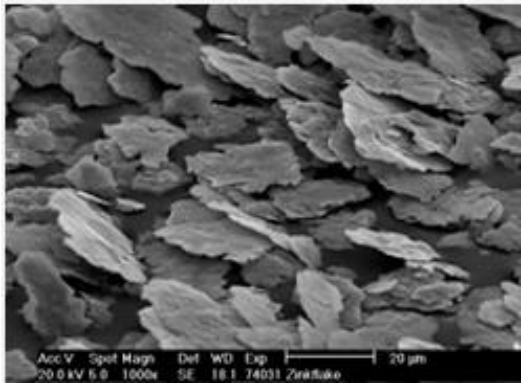
Automotive Needs	Eos Development Approach
• Sloshing of electrolyte	• Viscosify electrolyte
• Low Temperature	• Electrolyte formulation, viscosifier with antifreeze characteristics
• High Temperature	• Electrolyte management system and self-filling/healing system design
• Semi-Sealed Construction	• Alter electrode reactions, engineer case
• Sustained high power	• Optimize power by enhancing chemistry; match w/ Li-ion, lead-acid, or capacitor

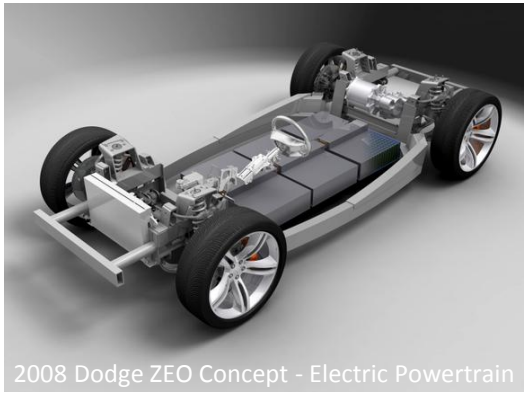
24 months of joint development could solve engineering—not fundamental science—challenges to create a low cost, long range vehicle battery

Eos Vista Zinc-Air Battery/Fuel Cell

Refueling Process Description:

1. The Eos Transfusion System replaces fully discharged electrolyte with zinc metal / electrolyte slurry
    - Turbulence used to suspend zinc metal flakes in electrolyte solution as it flows into the battery
    - Discharged electrolyte evacuated and returned to refueling station for re-use/recycling
2. Heavy zinc flakes settle on anode surface as each cell is refilled (think snow globe).
3. A brief conditioning charge lightly plates the zinc metal to the anode surface within each cell. Start to finish, the vehicle is fully recharged in 3-5 minutes.





2008 Dodge ZEO Concept - Electric Powertrain

Eos Vista battery will enable rapid electrolyte refueling *in addition* to electrical recharging

Summary

Eos Electric Vehicle Strategy	
Goal:	While maintaining separate and primary focus on grid-scale technology, partner with major EV players to develop and commercialize Eos automotive battery configurations
Eos Offering:	1. Eos zinc-air range extender 2. Eos refuelable zinc-air battery/fuel-cell
Potential Partners:	Battery manufacturers, Tier 1 suppliers, OEMs
Development Plan:	• Phase I (R&D) – Achieve and validate performance targets for range extender by 2013 • Phase II (Engineering) – Battery design and productization to deliver range extender prototype by 2014 • Phase III (Future Development) – Develop architecture and electrolyte exchange mechanism for refuelable battery/fuel-cell in 2015-16

www.eosenergystorage.com